

CSci 127: Introduction to Computer Science



hunter.cuny.edu/csci

Frequently Asked Questions

From email and tutoring.

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- ▶ *All previous final exams (and answer keys) on the website.*
- ▶ *UTAs in drop-in tutoring happy to review concepts and old exam questions.*
- ▶ *There will be opportunity for practice during our last meeting on 13 December.*

Handle Exam Anxiety – courtesy Dr. St. John

- Print out the past exams and do as much as possible in **1 hour**.
- Then grade yourselves, figure out which problems are similar to past problems, keeping all the exams you've done in a 3-hole notebook, 1 problem per page, organized by problem number, reinforces the similarity.
- Make a list of what does not make sense and asking the instructor.
- Attempting to do the exam in half the time means that in the real exam, you will have plenty of time.

Today's Topics



- Design Patterns: Searching
- Python Recap
- Machine Language
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic
- Final Exam: Format

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Predict what the code will do:

```
1 def search(nums, locate):
2     found = False
3     i = 0
4     while not found and i < len(nums):
5         print(nums[i])
6         if locate == nums[i]:
7             found = True
8         else:
9             i = i+1
10
11     return(found)
```

Predict what the code will do: II

```
11 nums= [1,4,10,6,5,42,9,8,12]
12 target = 6
13 if search(nums, target):
14     print(target, 'is in the list.')
15 else:
16     print(target, 'is not in the list.')
```

Simplified but a little tricky

```
1 def search(nums, locate):
2     i = 0
3     while i < len(nums) and locate!=nums[i]:
4         print(nums[i])
5         i = i+1
6
7     return (i < len(nums))
8     #If locate is in the list,
9     #then for some  $i < \text{len}(\text{nums})$ , we have
10    # $\text{locate} == \text{nums}[i]$ .
11    #If  $i \geq \text{len}(\text{nums})$ , this implies that all
12    #items are searched, no match is found.
```

Simplified but a little tricky

```
13 nums= [1,4,10,6,5,42,9,8,12]
14 target = 6
15 if search(nums, target):
16     print(target, 'is in the list.')
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```

Design Pattern: Linear Search

```
def search(nums, locate):
    found = False
    i = 0
    while not found and i < len(nums):
        print(nums[i])
        if locate == nums[i]:
            found = True
        else:
            i = i+1
    return(found)

nums= [1,4,10,6,5,42,9,8,12]
target = 6
if search(nums,target):
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```

- Example of **linear search**.

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- Start at the beginning of the list.

Design Pattern: Linear Search

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- Look at each item, one-by-one.

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```

- Example of **linear search**.
- Start at the beginning of the list.
- Look at each item, one-by-one.
- Stop when found, or the end of list reached.

Today's Topics



- Design Patterns: Searching
- **Python Recap**
- Machine Language
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic

Python & Circuits Review: 10 Weeks in 10 Minutes



A whirlwind tour of the semester, so far...

Week 1: print(), loops, comments, & turtles

```
1 #Texts following # are comments.  
2 #Comments are read by human beings, not  
   computer.  
3 #Name: Thomas Hunter  
4 #Date: September 1, 2017  
5 #This program prints: Hello, World!  
6  
7 print("Hello, World!")
```

Week 1: print(), loops, comments, & turtles

```
1 import turtle
2
3 taylor = turtle.Turtle()
4 taylor.color("purple")
5 taylor.shape("turtle")
6
7 n = 6
8 for i in range(n):
9     taylor.forward(100)
10    taylor.stamp()
11    taylor.left(360/n)
```

Week 2: variables, data types, more on loops & range()

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 - ▶ **int**: integer or whole numbers

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 - ▶ **list**: a sequence of items

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e.g. [3, 1, 4, 5, 9] or ['violet', 'purple', 'indigo']

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 - ▶ **class variables**: for complex objects, like turtles.

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e.g. [3, 1, 4, 5, 9] or ['violet', 'purple', 'indigo']
 - ▶ **class variables**: for complex objects, like turtles.
- More on loops & ranges:

Examples on loop and ranges

```
1 for num in [2,4,6,8,10]:  
2     print(num)
```






```
3  
4 sum = 0
```

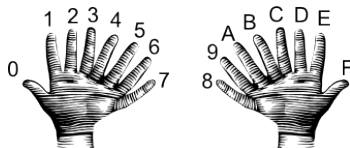
```
5 for x in range(0,12,2):  
6     print(x)  
7     sum += x
```

```
8  
9 print(sum)
```






```
10  
11 for c in 'ABCD':  
12     print(c)
```

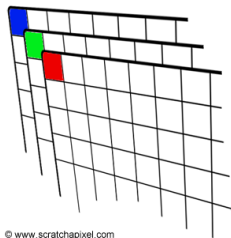
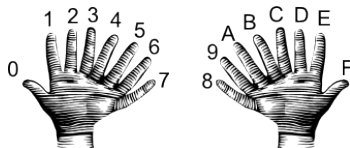
Week 3: colors, hex, slices, numpy & images

Color Name	HEX	Color
Black	#000000	
Navy	#000080	
DarkBlue	#00008B	
MediumBlue	#0000CD	
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Two Dimensional Array Slicing

```
1 import numpy as np
2
3 numRows = 6
4 numCols = 6
5 a = np.zeros((numRows, numCols))
6 #create a table with 6 rows and 6 columns,
7 #each element is initialized to be zero.
8 #Do not forget parentheses around
9 #numRows, numCols.
```

Two Dimensional Array Slicing: II

```
8 for i in range(numRows):
9     for j in range(numCols):
10         a[i, j] = i*10 + j
11 #range(numRows) returns [0, 1, 2, 3, 4, 5],
12 #where outer loop variable i chooses from.
13 #When i is 0, run
14 #     for j in range(numCols):
15 #         a[i, j] = i*10 + j
16 #When i is 1, run
17 #     for j in range(numCols):
18 #         a[i, j] = i*10 + j
19 #The last round of i is 5.
```

Two Dimensional Array Slicing: III

```
20 for i in range(numRows):
21     for j in range(numCols):
22         print("%3i"%(a[i, j]), end="")
23         #"%3i"%(a[i, j]) prints a[i, j] --
24         #element of a at ith row and
25         #jth column -- as an 3-digit int.
26         #"%3i" is a place holder and is
27         #filled by a[i, j].
28         #If a[i, j] does not have 3 digits,
29         #pad space(s) to the left.
30         #end="" print w/o a new line.
31
32 print() #print a new line after each row
```

Two Dimensional Array Slicing: III

32

```
print(a[0, 3:5])
```

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Two Dimensional Array Slicing: III

32

```
print(a[0, 3:5])
```

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

```
print
```

```
[3. 4.]
```


Two Dimensional Array Slicing: IV

33

```
print(a[4:, 4:])
```

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Two Dimensional Array Slicing: IV

33

```
print(a[4:, 4:])
```

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Print out

```
[[44. 45.]
```

```
 [54. 55.]]
```

Two Dimensional Array Slicing: V

34

```
print(a[:, 2])
```

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Two Dimensional Array Slicing: V

34

```
print(a[:, 2])
```

row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
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row \ col	0	1	2	3	4	5
0	0	1	2	3	4	5
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3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Print out

```
[ 2. 12. 22. 32. 42. 52.]
```

Two Dimensional Array Slicing: VI

35

```
print(a[2::2, ::2])
```

	0	1	2	3	4	5
0	0	1	2	3	4	5
1	10	11	12	13	14	15
2	20	21	22	23	24	25
3	30	31	32	33	34	35
4	40	41	42	43	44	45
5	50	51	52	53	54	55

Two Dimensional Array Slicing: VI

35

```
print(a[2::2, ::2])
```

	0	1	2	3	4	5		0	1	2	3	4	5
0	0	1	2	3	4	5	0	0	1	2	3	4	5
1	10	11	12	13	14	15	1	10	11	12	13	14	15
2	20	21	22	23	24	25	2	20	21	22	23	24	25
3	30	31	32	33	34	35	3	30	31	32	33	34	35
4	40	41	42	43	44	45	4	40	41	42	43	44	45
5	50	51	52	53	54	55	5	50	51	52	53	54	55

print

```
[[20. 22. 24.]  
 [40. 42. 44.]]
```

Week 4: design problem (cropping images) & decisions



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- First: specify inputs/outputs. *Input file name, output file name, upper, lower, left, right ("bounding box")*

Week 4: design problem (cropping images) & decisions



- First: specify inputs/outputs. *Input file name, output file name, upper, lower, left, right ("bounding box")*
- Next: write pseudocode.
 - ① Import numpy and pyplot.
 - ② Ask user for file names and dimensions for cropping.
 - ③ Save input file to an array.
 - ④ Copy the cropped portion to a new array.
 - ⑤ Save the new array to the output file.

Week 4: design problem (cropping images) & decisions



- First: specify inputs/outputs. *Input file name, output file name, upper, lower, left, right ("bounding box")*
- Next: write pseudocode.
 - ① Import numpy and pyplot.
 - ② Ask user for file names and dimensions for cropping.
 - ③ Save input file to an array.
 - ④ Copy the cropped portion to a new array.
 - ⑤ Save the new array to the output file.
- Next: translate to Python.

Grayed surrounding area of an image

```
1 #Leave middle 1/5 height * 1/2 width
   unchanged,
2 #gray the rest area of the image
3 import matplotlib.pyplot as plt
4 import numpy as np
5
6 fileName = input("Enter a file name: ")
7 img = plt.imread(fileName)
8
9 height = img.shape[0]
10 width = img.shape[1]
```

Grayed surrounding area of an image: II

```
11 #make the top 2/5 area gray
12 img[:height*2//5, :] = [0.5, 0.5, 0.5, 1]
13 #[0.5, 0.5, 0.5, 1] means
14 #red 0.5, green 0.5, blue 0.5 and opacity 1
15
16 #make the bottom 1/4 area gray
17 img[-height*2//5:, :] = [0.5, 0.5, 0.5, 1]
18 #img[-height*2//5:, :] same as
19 #img[height*3//5:, :]
20 ##height*2//5 from BOTTOM same as
21 #height*3//5 from TOP
22 #img[height*3//5:, :] = [0.5, 0.5, 0.5, 1]
```

Grayed surrounding area of an image: III

```
23 #make the left 1/4 area gray
24 img[:, :width//4] = [0.5, 0.5, 0.5, 1]
25
26 #make the right 1/4 area gray
27 img[:, width*3//4:] = [0.5, 0.5, 0.5, 1]
28 #img[:, width*3//4:] same as
29 #img[:, -width//4:]
30 #width*3//4 from LEFT same as
31 #width//4 from RIGHT
32 #img[:, -width//4:] = [0.5, 0.5, 0.5, 1]
33
34 plt.imshow(img)
35 plt.show()
```

Highlight part of image

```
1 #Leave middle 1/5 height * 1/2 width
2 #section unchanged,
3 #dim the rest area of the image
4 #It is like to highlight the middle part.
5
6 import matplotlib.pyplot as plt
7 import numpy as np
8
9 fileName = "csBridge.png"
10 #fileName = input("Enter a file name: ")
11 img = plt.imread(fileName)
```

Highlight part of image: II

```
12 height = img.shape[0]
13 width = img.shape[1]
14
15 #make the top 1/4 area gray
16 #img[:height*2//5, :] = [0.5, 0.5, 0.5, 1]
17 #[0.5, 0.5, 0.5, 1] means
18 #red 0.5, green 0.5, blue 0.5 and opacity 1
19 #unlike user created stripe images,
20 #some images have four channels.
21
22 #dim the top 1/4 area
23 img[:height*2//5, :, 3] = 0.5
```

Highlight part of image: III

```
24 #dim the bottom 1/4 area
25 img[-height*2//5:, :, 3] = 0.5
26 #img[-height*2//5:, :, 3] same as img[height
    *3//5:, :, 3]
27 #height*2//5 from BOTTOM same as height*3//5
    from TOP
28
29 #dim the left 1/4 area
30 img[:, :width//4, 3] = 0.5
```


Highlight part of image: IV

```
31 #dim the right 1/4 area
32 img[:, width*3//4:, 3] = 0.5
33 #img[:, width*3//4:, 3] same as
34 #img[:, -width//4:, 3]
35 #width*3//4 from LEFT same as
36 #width//4 from RIGHT
37
38 plt.imshow(img)
39 plt.show()
```

Crop image

```
1 #crop middle 1/5 * height * 1/2 * width area
2 import matplotlib.pyplot as plt
3 import numpy as np
4
5 fileName = "csBridge.png"
6 #fileName = input("Enter a file name: ")
7 img = plt.imread(fileName)
8
9 height = img.shape[0]
10 width = img.shape[1]
```

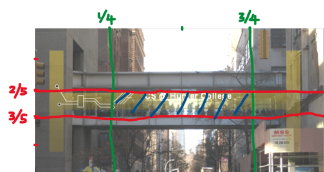
Crop image: II

```
1 img2 = img[height*2//5 : height*3//5, width  
2         *1//4 : width*3//4] ## cannot be replaced  
3         by /, indices need to be int.
```

```
4 plt.imshow(img2)
```

```
5 plt.show()
```

```
6 plt.imsave('cropped_image.png', img2)
```



Week 4: design problem (cropping images) & decisions

```
1 yearBorn = int(input("Enter year born: "))
2 if yearBorn < 1946:
3     print("Greatest Generation")
4 elif yearBorn <= 1964:
5     print("Baby Boomer")
6 elif yearBorn <= 1984:
7     print("Generation X")
8 elif yearBorn <= 2004:
9     print("Millennial")
10 else:
11     print("TBD")
```

Week 4: design problem (cropping images) & decisions: II

```
1 x = int(input("Enter number: "))
2
3 if x % 2 == 0:
4     print("Even number")
5 else:
6     print("Odd number")
```

Week 5: logical operators, truth tables & logical circuits

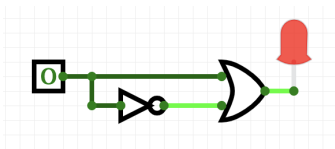
```
1 origin = "Indian Ocean"
2 winds = 100
3 if winds >= 74:
4     print("Major storms, called a ", end="")
5     if origin == "Indian Ocean" or origin == "
6         South Pacific":
7         print("cyclone.")
8     elif origin == "North Pacific":
9         print("typhoon.")
10    else:
11        print("hurricane.")
```

Week 5: logical operators, truth tables & logical circuits: II

```
1 visibility = 0.2
2 winds = 40
3 conditions = "blowing snow"
4 if (winds > 35) and (visibility < 0.25) and
5     (conditions == "blowing snow" or
6         conditions == "heavy snow"):
7     print("Blizzard!")
```

Week 5: logical operators, truth tables & logical circuits: III

in1		in2	returns:
False	and	False	False
False	and	True	False
True	and	False	False
True	and	True	True



Week 6: structured data, pandas, & more design

```
Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City,,,,,
All population figures are consistent with present-day boundaries,,,,,,
First census after the consolidation of the five boroughs,,,,,,
,,,,,
,,,,,
Year,Manhattan,Brooklyn,Queens,Bronx,Staten Island>Total
1698,4937,2017,,,727,7681
1771,21883,3623,,,2847,28423
1790,33131,45049,6159,1781,3827,49447
1800,40515,5740,6642,1755,4563,79215
1810,96373,40203,7444,2267,5347,119734
1820,123706,11187,8246,2782,6135,152056
1830,202589,20535,9049,3023,7082,242278
1840,312710,47613,14480,3344,10965,391114
1850,515547,138882,18593,8032,15061,696115
1860,813649,279122,32963,23593,25492,1174779
1870,942292,419801,45468,37393,33829,1470183
1880,1164673,599495,56559,51980,38991,1911690
1890,1441216,838547,87050,88908,51692,2507414
1900,1650093,1146582,152899,200507,67021,2437202
1910,2331542,1634351,284041,430980,85969,4766883
1920,2284103,2018296,469042,732016,116511,5620048
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1940,1889924,2698295,1297634,1394711,174441,7454995
1950,1940101,2738075,1550849,1452177,191555,78991957
1960,1698281,2627319,1809578,1424815,221993,7781984
1970,1539233,2602012,1986473,1471701,295443,7094862
1980,1428285,2210936,1801325,1168872,352121,7071439
1990,1487536,2300644,1951598,1203789,378977,7322564
2000,1537195,2465326,2229379,1332650,443728,8008278
2010,1494873,2504790,2230722,1385108,448730,81751123
2015,1644518,2636735,2339150,1455444,476558,8550405
```

nycHistPop.csv

In Lab 6

Week 6: structured data, pandas, & more design

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```
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```

nycHistPop.csv

In Lab 6

Week 6: structured data, pandas, & more design

```
import matplotlib.pyplot as plt
import pandas as pd
```

```
pop = pd.read_csv('nycHistPop.csv',skiprows=5)
```

```
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nycHistPop.csv

In Lab 6

Week 6: structured data, pandas, & more design

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1950,1940101,2738275,1500849,1451277,291555,78991957
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In Lab 6

Week 6: structured data, pandas, & more design

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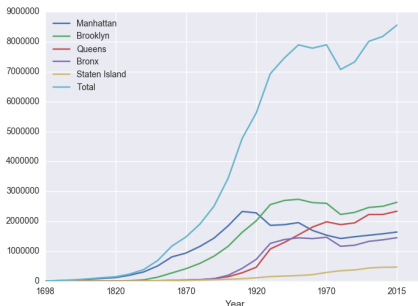
```
pop.plot(x="Year")
plt.show()
```

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```

nycHistPop.csv

In Lab 6



Week 7: functions

- Functions are a way to break code into pieces, that can be easily reused.

```
#Name: your name here
#Date: October 2017
#This program, uses functions,
#    says hello to the world!

def main():
    print("Hello, World!")

if __name__ == "__main__":
    main()
```

Week 7: functions

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```
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- Functions are a way to break code into pieces, that can be easily reused.
- Many languages require that all code must be organized with functions.

Week 7: functions

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Week 7: functions

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- Many languages require that all code must be organized with functions.
- The opening function is often called `main()`
- You **call** or **invoke** a function by typing its name, followed by any inputs, surrounded by parenthesis:

Week 7: functions

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Example: `print("Hello", "World")`

Week 7: functions

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- Many languages require that all code must be organized with functions.
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- You **call** or **invoke** a function by typing its name, followed by any inputs, surrounded by parenthesis:
Example: `print("Hello", "World")`
- Can write, or **define** your own functions,

Week 7: functions

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- Functions are a way to break code into pieces, that can be easily reused.
- Many languages require that all code must be organized with functions.
- The opening function is often called `main()`
- You **call** or **invoke** a function by typing its name, followed by any inputs, surrounded by parenthesis: Example: `print("Hello", "World")`
- Can write, or **define** your own functions, which are stored, until invoked or called.

Week 8: function parameters, github

- Functions can have **input parameters**.

```
def totalWithTax(food,tip):  
    total = 0  
    tax = 0.0875  
    total = food + food * tax  
    total = total + tip  
    return(total)  
  
lunch = float(input('Enter lunch total: '))  
lTip = float(input('Enter lunch tip: ' ))  
lTotal = totalWithTax(lunch, lTip)  
print('Lunch total is', lTotal)  
  
dinner= float(input('Enter dinner total: '))  
dTip = float(input('Enter dinner tip: ' ))  
dTotal = totalWithTax(dinner, dTip)  
print('Dinner total is', dTotal)
```

Week 8: function parameters, github

- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).

```
def totalWithTax(food,tip):  
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print('Dinner total is', dTotal)
```

Week 8: function parameters, github

- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).
- The “placeholders” in the function definition: **formal parameters**.

```
def totalWithTax(food,tip):  
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Week 8: function parameters, github

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- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).
- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**

Week 8: function parameters, github

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- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).
- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**
- Functions can also **return values** to where it was called.

Week 8: function parameters, github

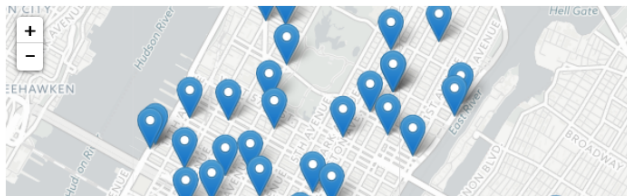
```
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```

Formal Parameters

Actual Parameters

- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).
- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**.
- Functions can also **return values** to where it was called.

Week 9: top-down design, folium, loops, and random()



```
def main():
    dataF = getData()
    latColName, lonColName = getColumnNames()
    lat, lon = getLocale()
    cityMap = folium.Map(location = [lat,lon], tiles = 'cartodbpositron', zoom_start=11)
    dotAllPoints(cityMap,dataF,latColName,lonColName)
    markAndFindClosest(cityMap,dataF,latColName,lonColName,lat,lon)
    writeMap(cityMap)
```

Week 10: more on loops, max design pattern, random()

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))
print('The distance entered is', dist)
```

- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
    trey.forward(10)
    a = random.randrange(0,360,90)
    trey.right(a)
```

Week 10: more on loops, max design pattern, random()

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dist = int(input('Enter distance: '))
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- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.
- Very useful for checking user input for correctness.

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- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.
- Very useful for checking user input for correctness.
- Python's built-in random package has useful methods for generating random whole numbers and real numbers.

Week 10: more on loops, max design pattern, random()

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- To use, must include:
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- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.
- Very useful for checking user input for correctness.
- Python's built-in random package has useful methods for generating random whole numbers and real numbers.
- To use, must include:
`import random.`
- The max design pattern provides a template for finding maximum value from a list.

Python & Circuits Review: 10 Weeks in 10 Minutes



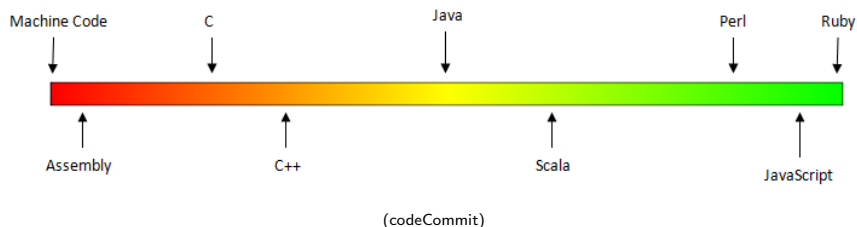
- Input/Output (I/O): `input()` and `print()`;
pandas for CSV files
- Types:
 - ▶ Primitive: `int`, `float`, `bool`, `string`;
 - ▶ Container: lists (but not dictionaries/hashtes or tuples)
- Objects: turtles (used but did not design our own)
- Loops: definite & indefinite
- Conditionals: `if-elif-else`
- Logical Expressions & Circuits
- Functions: parameters & returns
- Packages:
 - ▶ Built-in: `turtle`, `math`, `random`
 - ▶ Popular: `numpy`, `matplotlib`, `pandas`, `folium`

Today's Topics



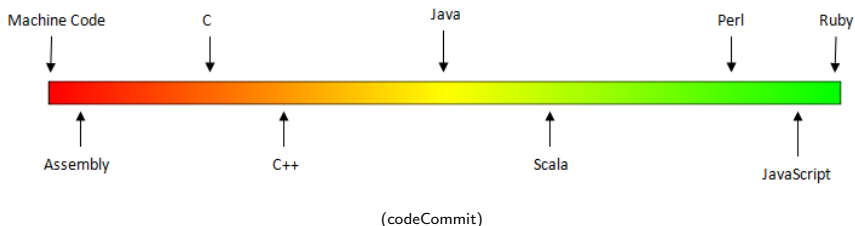
- Design Patterns: Searching
- Python Recap
- **Machine Language**
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic

Low-Level vs. High-Level Languages



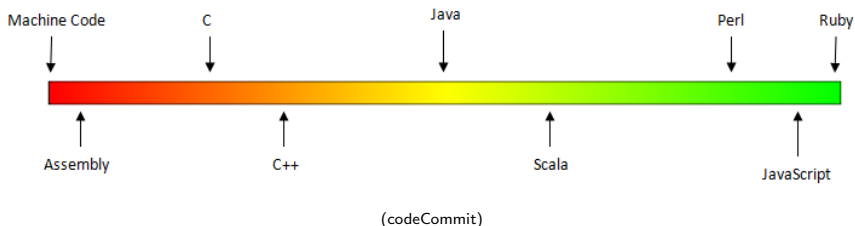
- Can view programming languages on a continuum.

Low-Level vs. High-Level Languages



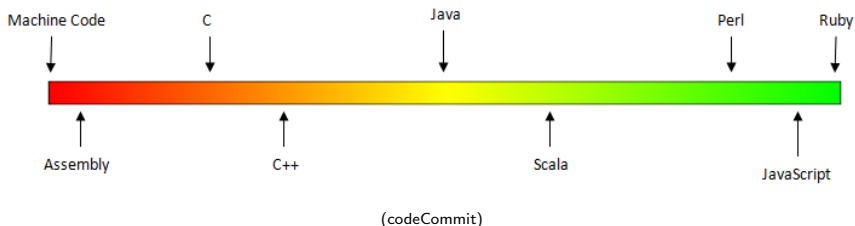
- Can view programming languages on a continuum.
- Those that directly access machine instructions & memory and have little abstraction are **low-level languages**

Low-Level vs. High-Level Languages



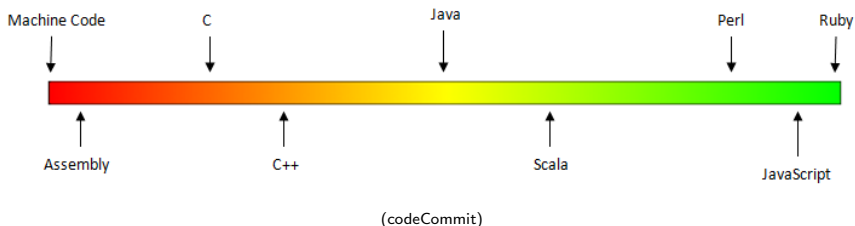
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Low-Level vs. High-Level Languages



- Can view programming languages on a continuum.
- Those that directly access machine instructions & memory and have little abstraction are **low-level languages** (e.g. machine language, assembly language).
- Those that have strong abstraction (allow programming paradigms independent of the machine details, such as complex variables, functions and looping that do not translate directly into machine code) are called **high-level languages**.

Low-Level vs. High-Level Languages

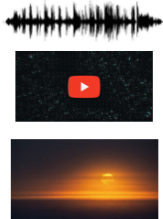


- Can view programming languages on a continuum.
- Those that directly access machine instructions & memory and have little abstraction are **low-level languages** (e.g. machine language, assembly language).
- Those that have strong abstraction (allow programming paradigms independent of the machine details, such as complex variables, functions and looping that do not translate directly into machine code) are called **high-level languages**.
- Some languages, like C, are in between– allowing both low level access and high level data structures.

Processing



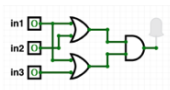
Dies ist ein Blindtext. An ihm lässt sich vieles über die Schrift ablesen, in der er gesetzt ist. Auf den ersten Blick wird der Grauwert der Schriftfläche sichtbar. Dann kann man prüfen, wie gut die Schrift zu lesen ist und wie sie auf den Leser wirkt. Dies ist ein Blindtext. An ihm lässt sich



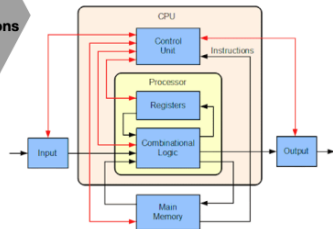
**Data
&
Instructions**



**Data
&
Instructions**

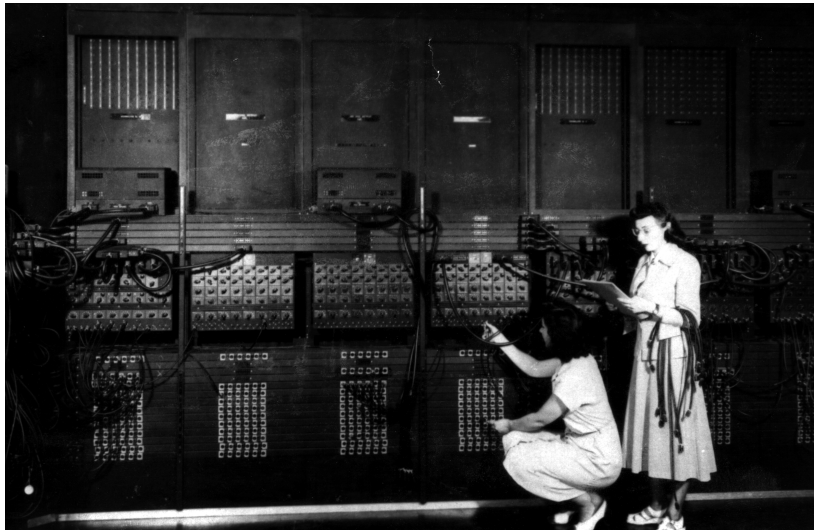


**Circuits (switches)
On/Off 1/0 Logic
Billions of switches/bits**



```
def totalWithTax(food,tip):
    total = 0
    tax = 0.0875
    total = food + food * tax
    total = total + tip
    return(total)
```


Machine Language



(Ruth Gordon & Ester Gerston programming the ENIAC, UPenn)

Machine Language

```
1 FOX 12:01a 23- 1
A 002000 C2 30 REP #$30
A 002002 18 CLC
A 002003 F8 SED
A 002004 A9 34 12 LDA #$1234
A 002007 69 21 43 ADC #$4321
A 00200A 8F 03 7F 01 STA $017F03
A 00200E D8 CLD
A 00200F E2 30 SEP #$30
A 002011 00 BRK
A 2012

r
PB PC NUmxDI2C .A .X .Y SP DP DB
; 00 E012 00110000 0000 0000 0002 CFFF 0000 00
g 2000

BREAK

PB PC NUmxDI2C .A .X .Y SP DP DB
; 00 2013 00110000 5555 0000 0002 CFFF 0000 00
m 7f03 7f03
>007F03 55 55 00 00 00 00 00 00 00 00 00 00 00 00 00:UU.....
█
```

(wiki)


Machine Language

- We will be writing programs in a simplified machine language, WeMIPS.

[illegible]

(wiki)

Machine Language



The screenshot shows a MIPS assembly program in a debugger. The program consists of several instructions: `REP #30`, `CLC`, `SED`, `LDR #01234`, `ROR #04321`, `STW #01789`, `CLD`, `SEP #30`, and `BRK`. The debugger shows the current instruction at address 00200C, which is `CLD`. The register values are: `$0: 00000000`, `$1: 00000000`, `$2: 00000000`, `$3: 00000000`, `$4: 00000000`, `$5: 00000000`, `$6: 00000000`, `$7: 00000000`, `$8: 00000000`, `$9: 00000000`, `$10: 00000000`, `$11: 00000000`, `$12: 00000000`, `$13: 00000000`, `$14: 00000000`, `$15: 00000000`, `$16: 00000000`, `$17: 00000000`, `$18: 00000000`, `$19: 00000000`, `$20: 00000000`, `$21: 00000000`, `$22: 00000000`, `$23: 00000000`, `$24: 00000000`, `$25: 00000000`, `$26: 00000000`, `$27: 00000000`, `$28: 00000000`, `$29: 00000000`, `$30: 00000000`, `$31: 00000000`. The program counter (PC) is 00200C. The status register (SR) is 00000000. The program is running in user mode.

(wiki)

- We will be writing programs in a simplified machine language, WeMIPS.
- It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.

Machine Language



```
002000 c2 30 REP #430
002002 10 CLC
002003 f0 SED
002004 40 34 12 LSH #1224
002007 60 21 43 RLC #4321
00200a 0f 03 7f 01 STN #017f03
00200c 00 CLJ
00200f e2 30 SEP #430
002011 00 BRX
002012

PC PC MIPS32C A X Y SP DP BB
: 00 f012 00110000 0000 0000 0002 cfff 0000 00
$ 2000

BREAK

PC PC MIPS32C A X Y SP DP BB
: 00 2013 00110000 5555 0000 0002 cfff 0000 00
n 1103 7f03
007f03 55 55 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

(wiki)

- We will be writing programs in a simplified machine language, WeMIPS.
- It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.
- Due to its small set of commands, processors can be designed to run those commands very efficiently.

Machine Language



(wiki)

- We will be writing programs in a simplified machine language, WeMIPS.
- It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.
- Due to its small set of commands, processors can be designed to run those commands very efficiently.
- More in future architecture classes....

“Hello World!” in Simplified Machine Language

```
1 # Store 'Hello world!' at the top of the
   stack
2 ADDI $sp, $sp, -13
3 ADDI $t0, $zero, 72 # 72 is ASCII code of 'H'
4 SB $t0, 0($sp)
5 ADDI $t0, $zero, 101 # e
6 SB $t0, 1($sp)
7 ADDI $t0, $zero, 108 # l
8 SB $t0, 2($sp)
9 ADDI $t0, $zero, 108 # l
10 SB $t0, 3($sp)
11 ADDI $t0, $zero, 111 # o
12 SB $t0, 4($sp)
```

“Hello World!” in Simplified Machine Language: II

```
13 ADDI $t0, $zero, 32 # (space)
14 SB $t0, 5($sp)
15 ADDI $t0, $zero, 119 # w
16 SB $t0, 6($sp)
17 ADDI $t0, $zero, 111 # o
18 SB $t0, 7($sp)
19 ADDI $t0, $zero, 114 # r
20 SB $t0, 8($sp)
21 ADDI $t0, $zero, 108 # l
22 SB $t0, 9($sp)
23 ADDI $t0, $zero, 100 # d
24 SB $t0, 10($sp)
```


“Hello World!” in Simplified Machine Language: II

```
25 ADDI $t0, $zero, 33 # !
26 SB $t0, 11($sp)
27 ADDI $t0, $zero, 0 # (null)
28 SB $t0, 12($sp)
29
30 ADDI $v0, $zero, 4 # 4 is for print string
31 ADDI $a0, $sp, 0
32 syscall # print to the log
```

WeMIPS

Line: 3 dis

Show/Hide Demos

Addition Doubler Stop Looper Stack Test Hello World

Code Gen Save String Interactive Binary2 Decimal Decimal2 Binary

Debug

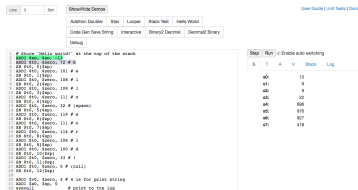
```
1 # Store "hello world!" at the top of the stack
2 ADDUI $a0, $zero, 32 # 0
3 ROR $t0, $t0
4 ADDUI $t0, $zero, 101 # e
5 DD $t0, 1($t0)
6 ADDUI $t0, $zero, 108 # l
7 DD $t0, 6($t0)
8 ADDUI $t0, $zero, 108 # l
9 DD $t0, 6($t0)
10 ADDUI $t0, $zero, 111 # o
11 DD $t0, 6($t0)
12 ADDUI $t0, $zero, 32 # (space)
13 DD $t0, 6($t0)
14 ADDUI $t0, $zero, 119 # w
15 DD $t0, 6($t0)
16 ADDUI $t0, $zero, 114 # u
17 DD $t0, 6($t0)
18 ADDUI $t0, $zero, 114 # u
19 DD $t0, 6($t0)
20 ADDUI $t0, $zero, 108 # l
21 DD $t0, 6($t0)
22 ADDUI $t0, $zero, 108 # l
23 DD $t0, 6($t0)
24 ADDUI $t0, $zero, 33 # !
25 DD $t0, 1($t0)
26 ADDUI $t0, $zero, 0 # (null)
27 DD $t0, 1($t0)
28 ADDUI $t0, $zero, 6 # 6 in for print string
29 ADDUI $a0, $a0, 0
30 syscall # print to the log
```

Step Run ☐ Enable auto-switching

S	T	A	V	Stack	Log
				a0:	10
				t0:	9
				a0:	9
				a0:	22
				a0:	695
				a0:	970
				a0:	927
				a0:	418

(Demo with WeMIPS)

MIPS Commands



```
1 # Store "hello world" at the top of the stack
2 ADDUI $0, $zero, 128
3 SW $0, 0($0)
4
5 ADDUI $0, $zero, 191 # n
6 SW $0, 10($0)
7
8 ADDUI $0, $zero, 100 # i
9 SW $0, 20($0)
10
11 ADDUI $0, $zero, 100 # j
12 SW $0, 30($0)
13
14 ADDUI $0, $zero, 32 # (space)
15 SW $0, 40($0)
16
17 ADDUI $0, $zero, 131 # n
18 SW $0, 50($0)
19
20 SW $0, 60($0)
21
22 ADDUI $0, $zero, 100 # i
23 SW $0, 70($0)
24
25 ADDUI $0, $zero, 131 # n
26 SW $0, 80($0)
27
28 SW $0, 90($0)
29
30 ADDUI $0, $zero, 100 # j
31 SW $0, 100($0)
32
33 ADDUI $0, $zero, 32 # i
34 SW $0, 110($0)
35
36 ADDUI $0, $zero, 0 # (null)
37 SW $0, 120($0)
38
39 ADDUI $0, $zero, 4 # n is for print string
40 ADDUI $0, $zero, 8 # print to the log
41 syscall
```

	\$	T	A	V	Stack	Log
\$0					10	
\$1					9	
\$2					8	
\$3					22	
\$4					856	
\$5					817	
\$6					418	

- **Registers:** locations for storing information that can be quickly accessed.

MIPS Commands

```
1 # Choose "hello world" as the top of the stack
2 ADDUI $s0, $zero, 12 # 12
3 SB $s0, 0($zero)
4 ADDUI $s1, $zero, 10 # 10
5 SB $s1, 4($zero)
6 ADDUI $s2, $zero, 100 # 100
7 SB $s2, 8($zero)
8 ADDUI $s3, $zero, 111 # 111
9 SB $s3, 12($zero)
10 ADDUI $s4, $zero, 12 # 12
11 SB $s4, 16($zero)
12 ADDUI $s5, $zero, 110 # 110
13 SB $s5, 20($zero)
14 ADDUI $s6, $zero, 111 # 111
15 SB $s6, 24($zero)
16 ADDUI $s7, $zero, 114 # 114
17 SB $s7, 28($zero)
18 ADDUI $s8, $zero, 100 # 100
19 SB $s8, 32($zero)
20 ADDUI $s9, $zero, 100 # 100
21 SB $s9, 36($zero)
22 ADDUI $s10, $zero, 10 # 10
23 SB $s10, 40($zero)
24 ADDUI $s11, $zero, 0 # (null)
25 SB $s11, 44($zero)
26 ADDUI $s12, $zero, 4 # 4 is for print ending
27 ADDUI $s13, $zero, 0 # print to the log
28 syscall
```

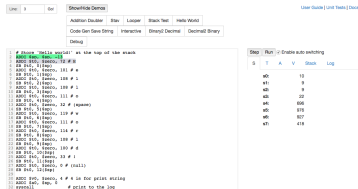
- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...

MIPS Commands

[illegible]

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
- **R Instructions:** Commands that use data in the registers:
add \$s1, \$s2, \$s3

MIPS Commands



The screenshot shows the MIPS simulator interface. On the left, there's a text area with assembly code. On the right, there's a register window showing the state of registers \$0 through \$31.

```
1 # Choose "Hello world" as the top of the stack
2 ADDI $0, $zero, 12 # R
3 SW $0, 12($0)
4 ADDI $0, $zero, 181 # R
5 SW $0, 181($0)
6 ADDI $0, $zero, 100 # I
7 SW $0, 100($0)
8 ADDI $0, $zero, 100 # I
9 SW $0, 100($0)
10 ADDI $0, $zero, 111 # R
11 SW $0, 111($0)
12 ADDI $0, $zero, 12 # (again)
13 SW $0, 12($0)
14 ADDI $0, $zero, 111 # R
15 SW $0, 111($0)
16 ADDI $0, $zero, 114 # R
17 SW $0, 114($0)
18 ADDI $0, $zero, 100 # I
19 SW $0, 100($0)
20 ADDI $0, $zero, 100 # R
21 SW $0, 100($0)
22 ADDI $0, $zero, 33 # I
23 SW $0, 33($0)
24 ADDI $0, $zero, 0 # (null)
25 SW $0, 0($0)
26 ADDI $0, $zero, 4 # 4 is for print ending
27 ADDI $0, $zero, 4 # print to the log
28 syscall
```

The register window on the right shows the following values:

Register	Value
\$0	12
\$1	9
\$2	9
\$3	22
\$4	100
\$5	100
\$6	111
\$7	111
\$8	12
\$9	111
\$10	114
\$11	100
\$12	100
\$13	100
\$14	33
\$15	0
\$16	4
\$17	4

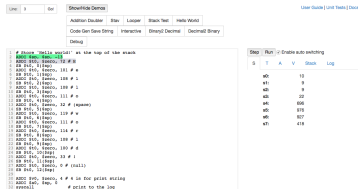
- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
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add \$s1, \$s2, \$s3 (Basic form: OP rd, rs, rt)
- **I Instructions:** instructions that also use intermediate values.

MIPS Commands

[illegible]

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add \$s1, \$s2, \$s3 (Basic form: OP rd, rs, rt)
- **I Instructions:** instructions that also use intermediate values.
addi \$s1, \$s2, 100

MIPS Commands



```
1 # Please "Hello world!" as the top of the main
2 addi $v0, $zero, 12 # 12
3 li $t0, 10
4 add $s0, $zero, 10 # s
5 li $t1, 1000
6 addi $t2, $zero, 100 # 2
7 li $t3, 10000
8 addi $t4, $zero, 100 # 1
9 li $t5, 1000
10 addi $t6, $zero, 111 # s
11 li $t7, 1000
12 addi $t8, $zero, 12 # (space)
13 li $t9, 1000
14 addi $t10, $zero, 111 # s
15 li $t11, 1000
16 addi $t12, $zero, 114 # s
17 li $t13, 1000
18 addi $t14, $zero, 100 # 1
19 li $t15, 1000
20 addi $t16, $zero, 100 # s
21 li $t17, 1000001
22 li $t18, 1000
23 addi $t19, $zero, 33 # 1
24 li $t20, 1000001
25 addi $t21, $zero, 0 # (null)
26 li $t22, 1000001
27 addi $t23, $zero, 4 # 4 is for print string
28 addi $t24, $zero, 4
29 syscall
30 # print to the log
```

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
- **R Instructions:** Commands that use data in the registers:
add \$s1, \$s2, \$s3 (Basic form: OP rd, rs, rt)
- **I Instructions:** instructions that also use intermediate values.
addi \$s1, \$s2, 100 (Basic form: OP rd, rs, imm)
- **J Instructions:** instructions that jump to another memory location.

MIPS Commands

[illegible]

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addi \$s1, \$s2, 100 (Basic form: OP rd, rs, imm)
- **J Instructions:** instructions that jump to another memory location.
j done

MIPS Commands

[illegible]

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
- **R Instructions:** Commands that use data in the registers:
add \$s1, \$s2, \$s3 (Basic form: OP rd, rs, rt)
- **I Instructions:** instructions that also use intermediate values.
addi \$s1, \$s2, 100 (Basic form: OP rd, rs, imm)
- **J Instructions:** instructions that jump to another memory location.
j done (Basic form: OP label)

Challenge:

Line: 3 Go!

Show/Hide Demos

[User Guide](#) | [Unit Tests](#) | [Docs](#)

Addition Doubler

Stav

Looper

Stack Test

Hello World

Code Gen Save String

Interactive

Binary2 Decimal

Decimal2 Binary

Debug

```
1 # Store 'Hello world!' at the top of the stack
2 ADDI $sp, $sp, -13
3 ADDI $t0, $zero, 72 # H
4 SB $t0, 0($sp)
5 ADDI $t0, $zero, 101 # e
6 SB $t0, 1($sp)
7 ADDI $t0, $zero, 108 # l
8 SB $t0, 2($sp)
9 ADDI $t0, $zero, 108 # l
10 SB $t0, 3($sp)
11 ADDI $t0, $zero, 111 # o
12 SB $t0, 4($sp)
13 ADDI $t0, $zero, 32 # (space)
14 SB $t0, 5($sp)
15 ADDI $t0, $zero, 119 # w
16 SB $t0, 6($sp)
17 ADDI $t0, $zero, 111 # o
18 SB $t0, 7($sp)
19 ADDI $t0, $zero, 114 # r
20 SB $t0, 8($sp)
21 ADDI $t0, $zero, 108 # l
22 SB $t0, 9($sp)
23 ADDI $t0, $zero, 100 # d
24 SB $t0, 10($sp)
25 ADDI $t0, $zero, 33 # !
26 SB $t0, 11($sp)
27 ADDI $t0, $zero, 0 # (null)
28 SB $t0, 12($sp)
29
30 ADDI $v0, $zero, 4 # 4 is for print string
31 ADDI $a0, $sp, 0
32 syscall # print to the log
```

Step Run ☒ Enable auto switching

S	T	A	V	Stack	Log
				s0:	10
				s1:	9
				s2:	9
				s3:	22
				s4:	696
				s5:	976
				s6:	927
				s7:	418

Write a program that prints out the alphabet: a b c d ... x y z

WeMIPS

Line: 3 dis

Show/Hide Demos

User Guide | Unit Tests | Docs

Addition Doubler Stop Looper Stack Test Hello World

Code Gen Save String Interactive Binary2 Decimal Decimal2 Binary

Debug

```
1 # Store "hello world!" at the top of the stack
2 ADDUI $a0, $zero, 32 # 0
3 RUI $a0, 1($a0)
4 ADDUI $t0, $zero, 101 # e
5 LD $t0, 1($a0)
6 ADDUI $t0, $zero, 108 # l
7 LD $t0, 2($a0)
8 ADDUI $t0, $zero, 108 # l
9 LD $t0, 3($a0)
10 ADDUI $t0, $zero, 111 # o
11 LD $t0, 4($a0)
12 ADDUI $t0, $zero, 32 # (space)
13 LD $t0, 5($a0)
14 ADDUI $t0, $zero, 119 # w
15 SW $t0, 6($a0)
16 ADDUI $t0, $zero, 114 # u
17 LD $t0, 7($a0)
18 ADDUI $t0, $zero, 104 # r
19 LD $t0, 8($a0)
20 ADDUI $t0, $zero, 108 # l
21 LD $t0, 9($a0)
22 ADDUI $t0, $zero, 103 # d
23 LD $t0, 10($a0)
24 ADDUI $t0, $zero, 33 # !
25 SW $t0, 11($a0)
26 ADDUI $t0, $zero, 0 # (null)
27 LD $t0, 12($a0)
28
29 ADDUI $v0, $zero, 6 # 4 in for print string
30 ADDUI $a0, $v0, 0
31 syscall # print to the log
```

Step Run ☐ Enable auto-switching

S	T	A	V	Stack	Log
a0:				10	
t0:				9	
a0:				9	
a0:				22	
a0:				695	
a0:				970	
a0:				927	
a0:				418	

(Demo with WeMIPS)

Today's Topics



- Design Patterns: Searching
- Python Recap
- Machine Language
- **Machine Language: Jumps & Loops**
- Binary & Hex Arithmetic

Loops & Jumps in Machine Language

- Instead of built-in looping structures like `for` and `while`, you create your own loops by “jumping” to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.



Loops & Jumps in Machine Language

- Instead of built-in looping structures like `for` and `while`, you create your own loops by “jumping” to the location in the program.
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- Then give a command to jump to that location.



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- Different kinds of jumps:



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- Different kinds of jumps:
 - ▶ **Unconditional:** `j Done` will jump to the address with label `Done`.



Loops & Jumps in Machine Language

- Instead of built-in looping structures like `for` and `while`, you create your own loops by “jumping” to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.
- Different kinds of jumps:
 - ▶ **Unconditional:** `j Done` will jump to the address with label `Done`.
 - ▶ **Branch if Equal:** `beq $s0 $s1 DoAgain` will jump to the address with label `DoAgain` if the registers `$s0` and `$s1` contain the same value.



Loops & Jumps in Machine Language

- Instead of built-in looping structures like `for` and `while`, you create your own loops by “jumping” to the location in the program.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.
- Different kinds of jumps:
 - ▶ **Unconditional:** `j Done` will jump to the address with label `Done`.
 - ▶ **Branch if Equal:** `beq $s0 $s1 DoAgain` will jump to the address with label `DoAgain` if the registers `$s0` and `$s1` contain the same value.
 - ▶ See reading for more variations.



Print alphabet table in Simplified Machine Language: II

```
1 ADDI $sp, $sp, -27 #setup stack, 26 letters +  
  1 null  
2 ADDI $t0, $zero, 97 #save ASCII of 'a' to $t0  
3 ADDI $s2, $zero, 26 #set $s2 to be 26, track  
  whether 26 is reached or not  
4 SETUP:SB $t0, 0($sp) #save contents of $t0 to  
  stack  
5 ADDI $sp, $sp, 1 #increment the stack  
6 ADDI $s2, $s2, -1 #subtract 1 from $s2  
7 ADDI $t0, $t0, 1 #increment the letter  
8 BEQ $s2, $zero, DONE  
9 J SETUP
```

Print alphabet table in Simplified Machine Language: II

```
10 DONE:ADDI $t0, $zero, 0 #set null
11 SB $t0, 0($sp)
12 ADDI $sp, $sp, -26
13 ADDI $v0, $zero, 4 #$v0 is 4 means to print
14 ADDI $a0, $sp, 0 #set $a0 to stack pointer
15 syscall
```

Jump Demo

Line: 18 Go!

Show/Hide Demos

[User Guide](#) | [Unit Tests](#) | [Docs](#)

```
1
2 ADDI $sp, $sp, -27      # Set up stack
3 ADDI $s3, $zero, 1     # Store 1 in a register
4 ADDI $t0, $zero, 97    # Set $t0 at 97 (a)
5 ADDI $s2, $zero, 26    # Use to test when you reach 26
6 SETUP: SB $t0, 0($sp)   # Next letter in $t0
7 ADDI $sp, $sp, 1       # Increment the stack
8 SUB $s2, $s2, $s3      # Decrease the counter by 1
9 ADDI $t0, $t0, 1       # Increment the letter
10 BEQ $s2, $zero, DONE   # Jump to done if $s2 == 0
11 J SETUP                # Else, jump back to SETUP
12 DONE: ADDI $t0, $zero, 0 # Null (0) to terminate string
13 SB $t0, 0($sp)         # Add null to stack
14 ADDI $sp, $sp, -26     # Set up stack to print
15 ADDI $v0, $zero, 4     # 4 is for print string
16 ADDI $a0, $sp, 0       # Set $a0 to stack pointer
17 syscall                # Print to the log
```

(Demo
with
WeMIPS)

Step **Run** ☒ Enable auto switching

S T A V Stack Log

Clear Log

Emulation complete, returning to line 1

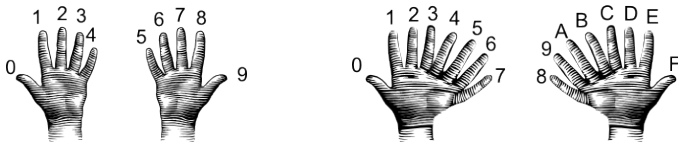
abcdefghijklmnopqrstuvwxyz

Today's Topics



- Design Patterns: Searching
- Python Recap
- Machine Language
- Machine Language: Jumps & Loops
- **Binary & Hex Arithmetic**

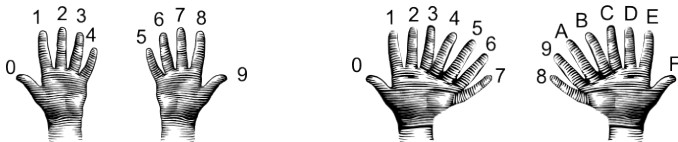
Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
 - ▶ Convert first digit to decimal and multiple by 16.

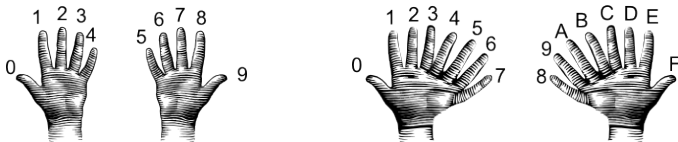
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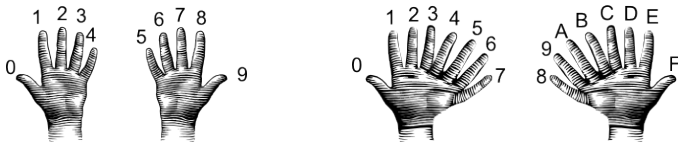
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 - ▶ Example: what is 2A as a decimal number?

Hexadecimal to Decimal: Converting Between Bases



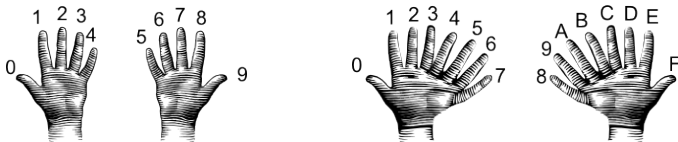
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2 in decimal is 2.

Hexadecimal to Decimal: Converting Between Bases



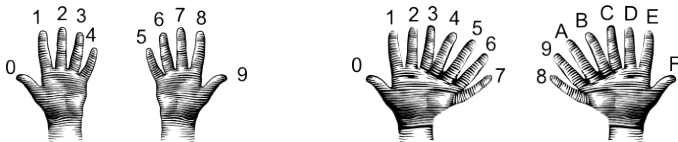
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- ▶ Convert first digit to decimal and multiple by 16.
- ▶ Convert second digit to decimal and add to total.
- ▶ Example: what is 2A as a decimal number?

2 in decimal is 2. 2×16 is 32.

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

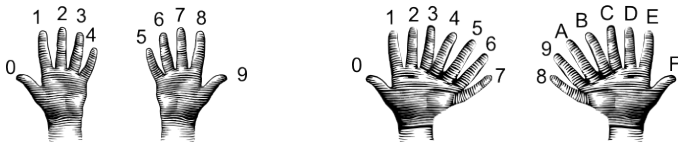
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- ▶ Convert first digit to decimal and multiple by 16.
- ▶ Convert second digit to decimal and add to total.
- ▶ Example: what is 2A as a decimal number?

2 in decimal is 2. 2×16 is 32.

A in decimal digits is 10.

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):

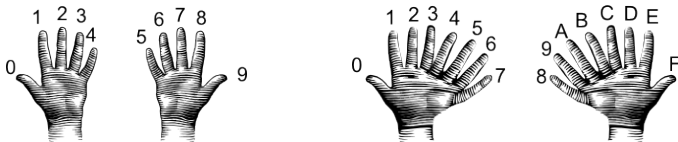
- ▶ Convert first digit to decimal and multiple by 16.
- ▶ Convert second digit to decimal and add to total.
- ▶ Example: what is 2A as a decimal number?

2 in decimal is 2. 2×16 is 32.

A in decimal digits is 10.

$32 + 10$ is 42.

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):

- ▶ Convert first digit to decimal and multiple by 16.
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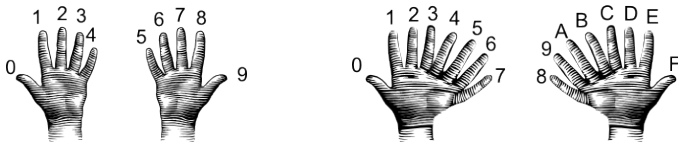
A in decimal digits is 10.

$32 + 10$ is 42.

Answer is 42.

- ▶ Example: what is 99 as a decimal number?

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):

- ▶ Convert first digit to decimal and multiple by 16.
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2 in decimal is 2. 2×16 is 32.

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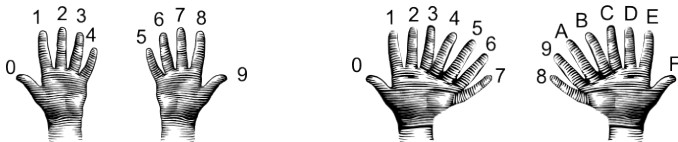
$32 + 10$ is 42.

Answer is 42.

- ▶ Example: what is 99 as a decimal number?

9 in decimal is 9.

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):

- ▶ Convert first digit to decimal and multiple by 16.
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2 in decimal is 2. 2×16 is 32.

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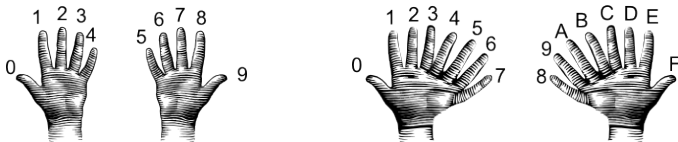
$32 + 10$ is 42.

Answer is 42.

- ▶ Example: what is 99 as a decimal number?

9 in decimal is 9. 9×16 is 144.

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):

- ▶ Convert first digit to decimal and multiple by 16.
- ▶ Convert second digit to decimal and add to total.
- ▶ Example: what is 2A as a decimal number?

2 in decimal is 2. 2×16 is 32.

A in decimal digits is 10.

$32 + 10$ is 42.

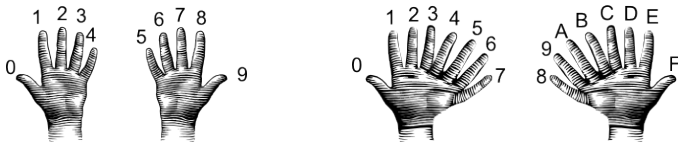
Answer is 42.

- ▶ Example: what is 99 as a decimal number?

9 in decimal is 9. 9×16 is 144.

9 in decimal digits is 9

Hexadecimal to Decimal: Converting Between Bases



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$32 + 10$ is 42.

Answer is 42.

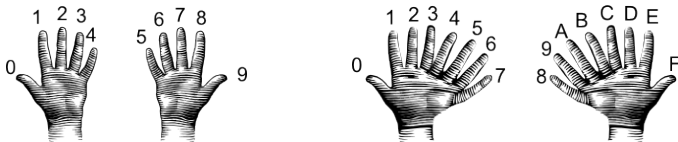
- ▶ Example: what is 99 as a decimal number?

9 in decimal is 9. 9×16 is 144.

9 in decimal digits is 9

$144 + 9$ is 153.

Hexadecimal to Decimal: Converting Between Bases



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$32 + 10$ is 42.

Answer is 42.

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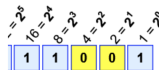
9 in decimal is 9. 9×16 is 144.

9 in decimal digits is 9

$144 + 9$ is 153.

Answer is 153.

Decimal to Binary: Converting Between Bases

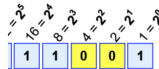


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- From decimal to binary:

- ▶ Divide by 128 ($= 2^7$). Quotient is the first digit.

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- From decimal to binary:

- ▶ Divide by 128 ($= 2^7$). Quotient is the first digit.
- ▶ Divide remainder by 64 ($= 2^6$). Quotient is the next digit.

Decimal to Binary: Converting Between Bases



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● From decimal to binary:

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Decimal to Binary: Converting Between Bases

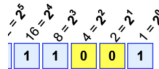


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Decimal to Binary: Converting Between Bases



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Decimal to Binary: Converting Between Bases

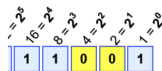


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Decimal to Binary: Converting Between Bases



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Decimal to Binary: Converting Between Bases

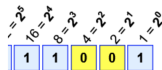


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Decimal to Binary: Converting Between Bases

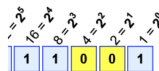


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- ▶ Example: what is 130 in binary notation?

Decimal to Binary: Converting Between Bases



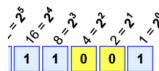
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- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2.

Decimal to Binary: Converting Between Bases



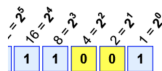
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- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1:

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

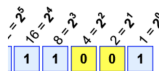
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- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2.

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

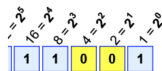
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Decimal to Binary: Converting Between Bases



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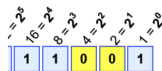
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130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2. Next digit is 0: 10...

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

● From decimal to binary:

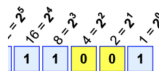
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- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2.

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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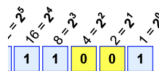
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- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2. Next digit is 0:

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

From decimal to binary:

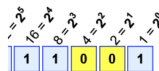
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- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2. Next digit is 0: 100...

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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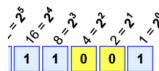
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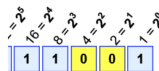
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Decimal to Binary: Converting Between Bases



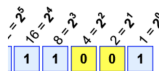
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Decimal to Binary: Converting Between Bases



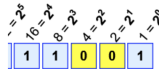
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Decimal to Binary: Converting Between Bases



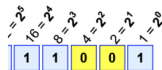
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Decimal to Binary: Converting Between Bases



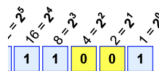
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Decimal to Binary: Converting Between Bases



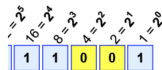
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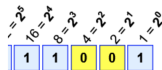
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Decimal to Binary: Converting Between Bases



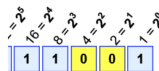
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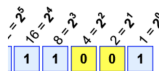
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Decimal to Binary: Converting Between Bases



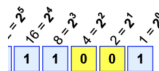
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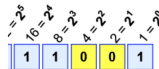
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2/2 is 1 rem 0. Next digit is 1: 1000001...

Adding the last remainder:

10000010

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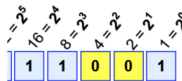
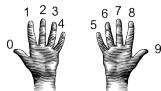
2/4 is 0 remainder 2. Next digit is 0: 100000...

2/2 is 1 rem 0. Next digit is 1: 1000001...

Adding the last remainder: 10000010



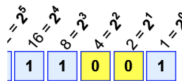
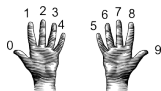
Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: what is 99 in binary notation?

Decimal to Binary: Converting Between Bases

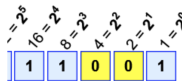
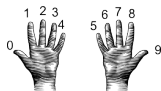


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- Example: what is 99 in binary notation?

99/128 is 0 rem 99.

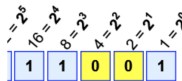
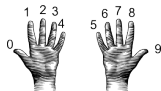
Decimal to Binary: Converting Between Bases



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- Example: what is 99 in binary notation?
99/128 is 0 rem 99. First digit is 0:

Decimal to Binary: Converting Between Bases



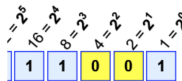
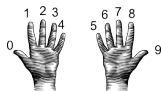
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99/64 is 1 rem 35.

Decimal to Binary: Converting Between Bases



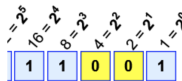
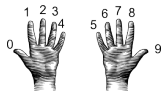
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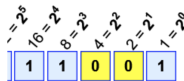
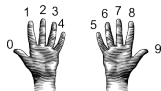
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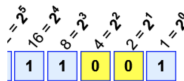
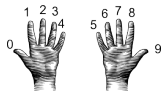
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35/32 is 1 rem 3.

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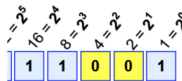
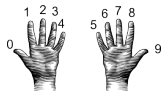
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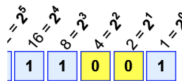
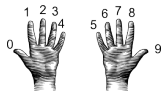
- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

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35/32 is 1 rem 3. Next digit is 1: 011...

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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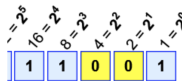
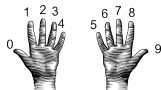
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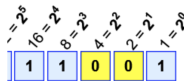
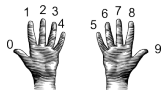
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Decimal to Binary: Converting Between Bases

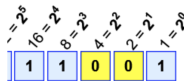
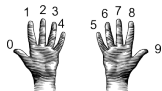


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Decimal to Binary: Converting Between Bases



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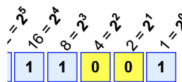
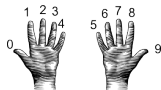
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3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3.

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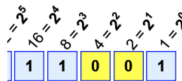
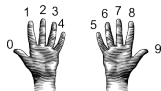
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Decimal to Binary: Converting Between Bases

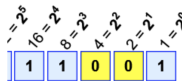
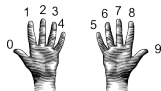


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Decimal to Binary: Converting Between Bases

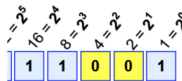
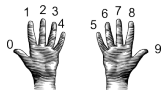


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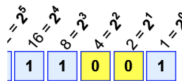
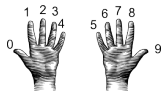
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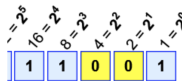
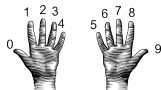
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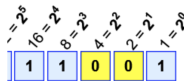
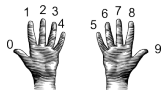
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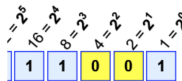
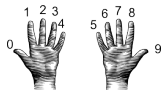
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Decimal to Binary: Converting Between Bases

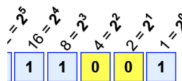
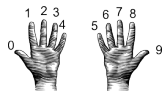


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3/4 is 0 remainder 3. Next digit is 0:	011000...
3/2 is 1 rem 1. Next digit is 1:	0110001...

Decimal to Binary: Converting Between Bases

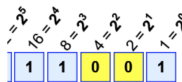
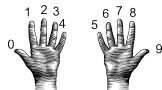


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Adding the last remainder:	01100011

Decimal to Binary: Converting Between Bases



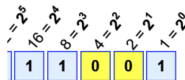
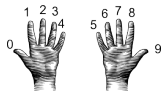
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Adding the last remainder:	01100011

Answer is 1100011.

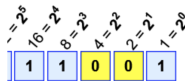
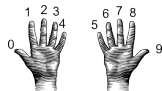
Binary to Decimal: Converting Between Bases



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- From binary to decimal:
 - Set sum = last digit.

Binary to Decimal: Converting Between Bases

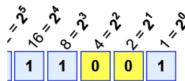
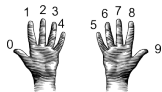


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- From binary to decimal:

- ▶ Set sum = last digit.
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Binary to Decimal: Converting Between Bases

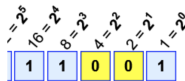
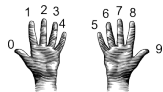


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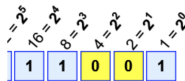
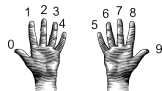


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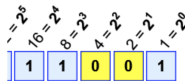
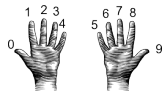


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- ▶ Multiply next digit by $16 = 2^4$. Add to sum.

Binary to Decimal: Converting Between Bases

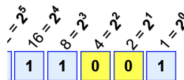


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Binary to Decimal: Converting Between Bases

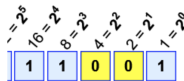
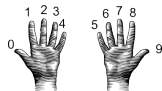


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Binary to Decimal: Converting Between Bases

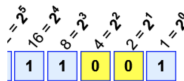


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- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
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Binary to Decimal: Converting Between Bases

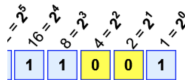
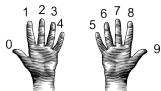


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- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.

Binary to Decimal: Converting Between Bases



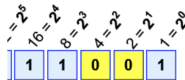
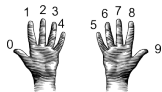
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- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with:

Binary to Decimal: Converting Between Bases



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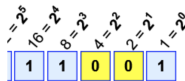
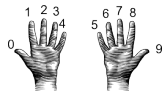
● From binary to decimal:

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- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1

$0 \times 2 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

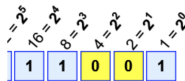
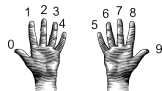
● From binary to decimal:

- ▶ Set sum = last digit.
- ▶ Multiply next digit by $2 = 2^1$. Add to sum.
- ▶ Multiply next digit by $4 = 2^2$. Add to sum.
- ▶ Multiply next digit by $8 = 2^3$. Add to sum.
- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1

$0 \times 2 = 0$. Add 0 to sum: 1

Binary to Decimal: Converting Between Bases



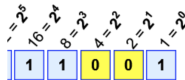
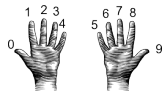
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

From binary to decimal:

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- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum:

Binary to Decimal: Converting Between Bases



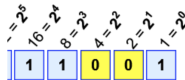
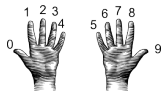
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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- ▶ Set sum = last digit.
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- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum: 5

Binary to Decimal: Converting Between Bases



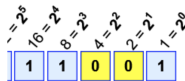
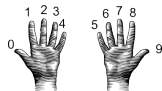
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

● From binary to decimal:

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- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum: 5
 $1 \times 8 = 8$. Add 8 to sum:

Binary to Decimal: Converting Between Bases



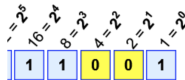
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with:	1
$0 \times 2 = 0$. Add 0 to sum:	1
$1 \times 4 = 4$. Add 4 to sum:	5
$1 \times 8 = 8$. Add 8 to sum:	13

Binary to Decimal: Converting Between Bases



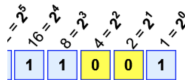
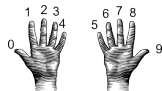
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- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum: 5
 $1 \times 8 = 8$. Add 8 to sum: 13
 $1 \times 16 = 16$. Add 16 to sum:

Binary to Decimal: Converting Between Bases



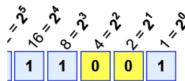
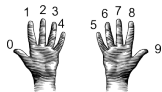
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum: 5
 $1 \times 8 = 8$. Add 8 to sum: 13
 $1 \times 16 = 16$. Add 16 to sum: 29

Binary to Decimal: Converting Between Bases



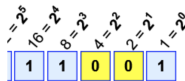
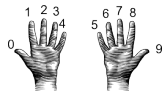
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- ▶ Multiply next digit by $8 = 2^3$. Add to sum.
- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum: 5
 $1 \times 8 = 8$. Add 8 to sum: 13
 $1 \times 16 = 16$. Add 16 to sum: 29
 $1 \times 32 = 32$. Add 32 to sum:

Binary to Decimal: Converting Between Bases



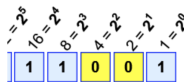
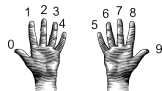
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- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum: 5
 $1 \times 8 = 8$. Add 8 to sum: 13
 $1 \times 16 = 16$. Add 16 to sum: 29
 $1 \times 32 = 32$. Add 32 to sum: 61

Binary to Decimal: Converting Between Bases



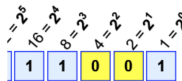
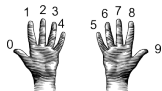
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with:	1
$0 \times 2 = 0$. Add 0 to sum:	1
$1 \times 4 = 4$. Add 4 to sum:	5
$1 \times 8 = 8$. Add 8 to sum:	13
$1 \times 16 = 16$. Add 16 to sum:	29
$1 \times 32 = 32$. Add 32 to sum:	61

Binary to Decimal: Converting Between Bases

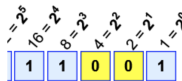
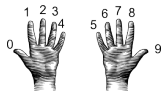


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with:

Binary to Decimal: Converting Between Bases



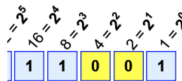
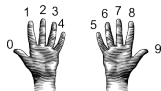
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases



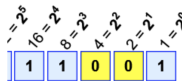
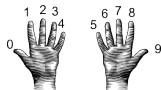
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum: 0

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

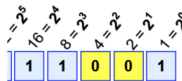
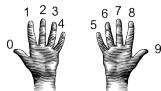
- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum:

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

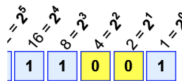
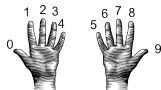
- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum: 4

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

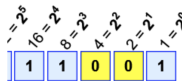
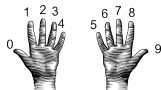
Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

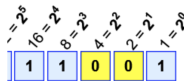
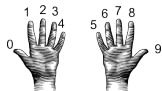
Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum: 4

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0

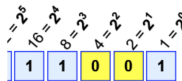
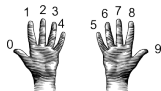
$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum: 4

$0 \times 16 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0

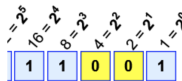
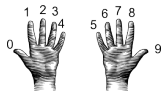
$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum: 4

$0 \times 16 = 0$. Add 0 to sum: 4

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum: 0

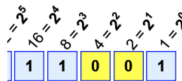
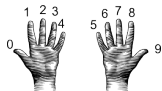
$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum: 4

$0 \times 16 = 0$. Add 0 to sum: 4

$1 \times 32 = 32$. Add 32 to sum:

Binary to Decimal: Converting Between Bases

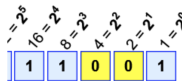
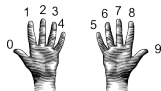


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with:	0
$0 \times 2 = 0$. Add 0 to sum:	0
$1 \times 4 = 4$. Add 4 to sum:	4
$0 \times 8 = 0$. Add 0 to sum:	4
$0 \times 16 = 0$. Add 0 to sum:	4
$1 \times 32 = 32$. Add 32 to sum:	36

Binary to Decimal: Converting Between Bases

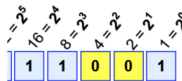
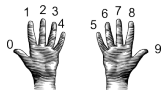


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0
 $0 \times 2 = 0$. Add 0 to sum: 0
 $1 \times 4 = 4$. Add 4 to sum: 4
 $0 \times 8 = 0$. Add 0 to sum: 4
 $0 \times 16 = 0$. Add 0 to sum: 4
 $1 \times 32 = 32$. Add 32 to sum: 36
 $0 \times 64 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases

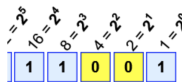
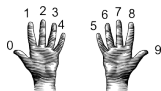


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with:	0
$0 \times 2 = 0$. Add 0 to sum:	0
$1 \times 4 = 4$. Add 4 to sum:	4
$0 \times 8 = 0$. Add 0 to sum:	4
$0 \times 16 = 0$. Add 0 to sum:	4
$1 \times 32 = 32$. Add 32 to sum:	36
$0 \times 64 = 0$. Add 0 to sum:	36

Binary to Decimal: Converting Between Bases

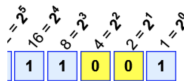
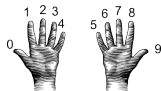


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with:	0
$0 \times 2 = 0$. Add 0 to sum:	0
$1 \times 4 = 4$. Add 4 to sum:	4
$0 \times 8 = 0$. Add 0 to sum:	4
$0 \times 16 = 0$. Add 0 to sum:	4
$1 \times 32 = 32$. Add 32 to sum:	36
$0 \times 64 = 0$. Add 0 to sum:	36
$1 \times 128 = 0$. Add 128 to sum:	

Binary to Decimal: Converting Between Bases

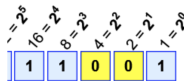
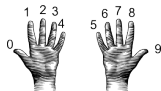


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with:	0
$0 \times 2 = 0$. Add 0 to sum:	0
$1 \times 4 = 4$. Add 4 to sum:	4
$0 \times 8 = 0$. Add 0 to sum:	4
$0 \times 16 = 0$. Add 0 to sum:	4
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$0 \times 64 = 0$. Add 0 to sum:	36
$1 \times 128 = 128$. Add 128 to sum:	164

Binary to Decimal: Converting Between Bases



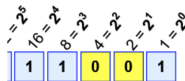
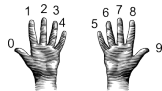
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Sum starts with:	0
$0 \times 2 = 0$. Add 0 to sum:	0
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$0 \times 64 = 0$. Add 0 to sum:	36
$1 \times 128 = 128$. Add 128 to sum:	164

The answer is 164.

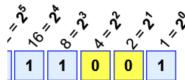
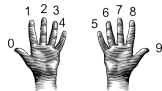
Design Challenge: Incrementers



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Simplest arithmetic: add one (“increment”) a variable.

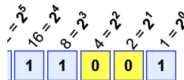
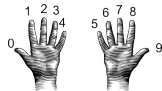
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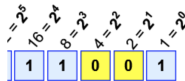
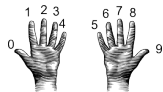


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```
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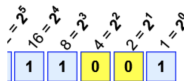
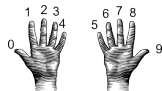


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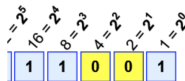
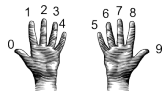


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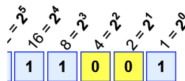
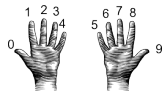


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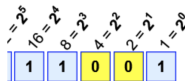
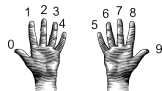


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Example: "1001" → "1010"

Recap



- Searching through data is a common task– built-in functions and standard design patterns for this.

Recap



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Final Overview: Format

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- Past exams available on webpage (includes answer keys).

Exam Options

Exam Times:

FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

13 December 2015

Exam Rules

- Show all your work. Your grade will be based on the work shown.
- The exam is closed book and closed notes with the exception of an $8\frac{1}{2} \times 11$ piece of paper filled with notes, program, etc.
- When taking the exam, you may have with you pens and pencils, and your note sheet.
- You may not use a computer, calculator, tablet, smart watch, or other electronic device.
- Do not open this exam until instructed to do so.

Hunter College upholds acts of academic dishonesty (e.g., plagiarism, cheating on examinations, obtaining unfair advantage, and falsification of records and official documents) as serious offenses against the values of intellectual honesty. The College is committed to upholding the CUNY Policy on Academic Integrity and will pursue cases of academic dishonesty according to the Hunter College Academic Integrity Procedures.

A student's use of notes or academic dishonesty will be reported to the Dean of Students and will result in suspension.

Name:
English:
Phone:
Signature:

Exam Options

Exam Times:

- Default Regular Time: Monday, December 19, 9-11am.

FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

13 December 2023

Exam Rules

- Before all your work. Your grade will be based on the work shown.
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Name:
Length:
Height:
Signature:

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CSci 127: Introduction to Computer Science
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FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

13 December 2023

Exam Rules

- You are all your work. Your grade will be based on the work shown.
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A statement that all cases of academic dishonesty will be reported to the Dean of Students and will result in suspension.	
Name:	
English:	
French:	
Spanish:	

Exam Options

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FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

13 December 2023

Exam Rules

- You have 45 minutes. Your grade will be based on the work shown.
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I understand that all cases of academic dishonesty will be reported to the Dean of Students and will result in sanctions.	
Name:	
English:	
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FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

13 December 2021

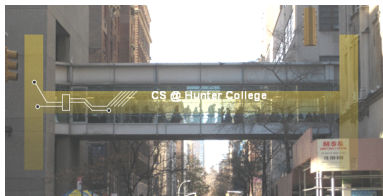
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- Score of your work. Your grade will be based on the work shown.
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Examinee Name (last, first, and middle initials) will be reported to the Dean of Students and will remain on record.
Name:
Length:
Height:
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Weekly Reminders!



Before next lecture, don't forget to:

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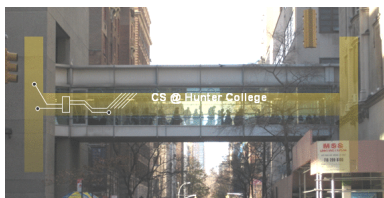
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- Take the Lecture Preview on Blackboard on Monday (or no later than 10am on Tuesday)

Lecture Slips & Writing Boards



- Hand your lecture slip to a UTA.
- Return writing boards as you leave.